Computational Fluid Dynamics Analysis Of A Resistance Muffler

BHAGATH SHAILENDER
M.Tech Student, Dept of Thermal, D.V.R College of Engineering and Technology, Sangareddy, Telangana, India

A.RAJNI KANTH
Assistant Professor,Dept of Mechanical, D.V.R College of Engineering and Technology, Sangareddy, Telangana, India

Abstract: **In this project, design and CFD (computational fluid dynamics) of a car muffler has been presented. The designing and CFD is done in the 3D Modelling Software, DSS SolidWorks 2014. The main objective of the project is to discover the components of car muffler, how it's built and how it is designed by the engineers. The problems they face while designing so. Car muffler is most widely used in the sports and family cars. We have made two different car muffler designs. With the help of flow simulation we will be able to get an idea of how a car muffler is able to absorb the sound produced by the engine and how its proper designing reduces back pressure results in increased horsepower of the engine. The CFD has been done for all the two models. Based on the result generated by the software we came to know that which one of the two models is the best.**

The turbulence optimisation is the main to reduce the acoustic effect or noise caused by the vehicle.

I. INTRODUCTION

Mufflers are installed within the exhaust system of most internal combustion engines, although the muffler is not designed to serve any primary exhaust function. The muffler is engineered as an **acoustic soundproofing device** designed to reduce the loudness of the sound pressure created by the engine .

Sound is a pressure wave formed from pulses of alternating high and low air pressure. These pulses make their way through the air at the speed of sound. In an engine, pulses are created when an exhaust valve opens and a burst of high-pressure gas suddenly enters the exhaust system. The molecules in this gas collide with the lower-pressure molecules in the pipe, causing them to stack up on each other. They in turn stack up on the molecules a little further down the pipe, leaving an area of low pressure behind. In this way, the sound wave makes its way down the pipe much faster than the actual gases do.

The key thing about sound waves is that the result at your ear is the sum of all the sound waves hitting your ear at that time. If you are listening to a band, even though you may hear several distinct sources of sound, the pressure waves hitting your ear drum all add together, so your ear drum only feels one pressure at any given moment. It is possible to produce a sound wave that is exactly the opposite of another wave. This is the basis for those noise-cancelling and this is what happens in a car muffler called as **destructive interference.**

Inside the muffler is a set of tubes. These tubes are designed to create reflected waves that interfere with each other or cancel each other out. The exhaust gases and the sound waves enter through the center tube. They bounce off the back wall of the muffler and are reflected through a hole into the main body of the muffler. They pass through a set of holes into another chamber, where they turn and go out the last pipe and leave the muffler.

A chamber called a **resonator** is connected to the first chamber by a hole. The resonator contains a specific volume of air and has a specific length that is calculated to produce a wave that cancels out a certain frequency of sound. When a wave hits the hole, part of it continues into the chamber and part of it is reflected. The wave travels through the chamber, hits the back wall of the muffler and bounces back out of the hole. The length of this chamber is calculated so that this wave leaves the resonator chamber just after the next wave reflects off the outside of the chamber. Ideally, the high-pressure part of the wave that came from the chamber will line up with the low-pressure part of the wave that was reflected off the outside of the chamber wall, and the two waves will cancel each other out.

So there are basically 2 types of mufflers

The conventional mufflers(resonating type): Favour more noise cancellation

Sound absorbant type: Favors high performance of engine but less noise cancellation

II. INTRODUCTION TO MUFFLERS

Muffler is defined as a mechanical device used to deplete the noise generated by an internal combustion engine.

The muffler not only reduces noise , but also

 @ 2013-2017 http://www.ijitr.com All rights Reserved.

diminishes vibrations .It was invented by 'Milton' and 'reeves' and they have taken patent in1897 at 'US PATENT' with application number:582485

Have you ever heard noise sent out by an internal combustion without the use of a muffler? It gives lot of discomfort for the passengers and the people around .The signal generated by the internal combustion engine has a very high frequency because the exhaust gases released into the atmosphere has approximately a pressure of 7 bar and 2000k temperature .Whenever the pressurised waves enter into the atmosphere at regular intervals of time ,it creates 'undesirable sound'. Not only that, it also creates a vibratory motion on the engine because of continuous pulses based on Newton's third law (action= - reaction).Here action is the high pressurised waves which are released from an IC engine and reaction is the vibration of the engine.

If you change the speed of the engine that automatically effects the frequency generation .The variation of speed is directly proportional to the frequency.

F=N*n/120 for 4-stroke engine

F=N*n/60 for 2-stroke engine

F=frequency generated=speed of the engine in rpm, n= number of cycles

Generally ,in ideal condition , the frequency generated is 73HZ and the frequency of the varies between 50HZ to 800HZ. In practicality, that range of continuous frequency is not possible.

So that is the reason why mufflers are introduced. By introducing the mufflers (silencer), the vibrations are diminished and the frequency of the muffler is also reduced to audible range .Because of the deployment of the muffler, the whole system has become more efficient which is always paramount .The muffler acts as the mediator between the engine and the atmosphere .So that is the reason why , the gases are cooled and neutralised before into the system.

The muffler also reduces the pressure of the exhaust gases before releasing into the atmosphere and therefore , most of the aberrations are reduced.

The muffler is a hollow cylindrical object which has 2 ports (one inlet and outlet).At the inlet , pressurised gas enters into the muffler chamber and by the time the gas comes out both the pressure and noise are significantly depleted.

The silencer can only reduce noise , but muffler can reduce both noise and vibration and which is why muffler is more advantageous.

In this unit , we have discussed about muflers and in the second unit , types of mufflers are discussed.

III. TYPES OF MUFFLERS

There are generally 2 types of mufflers which are listed below

1)Absorptive muffler

2)Reactive muffler

The two mufflers are also divided into several other mufflers based on direction, size, quantity etc .The main types are explained below:

1)*Absorptive muffler:*

The absorptive muffler is a special type of muffler used for reduction of noise and vibrations for a pleasure ride.

Construction:

The absorptive muffler has three main parts:

It has a hollow cylinder held circumferentially and the holes are held concentrically like oil and air filter.The outer surface is completely closed with noise absorbing material.The best absorbing material is glass fiber or cotton.Over the absorbing material , a protective layer is placed which gives extra protection not only to the absorbing material but also to other parts.

WORKING:

When high noise signal enters into one side of the parts, it automatically travels to the other side.It travels in the form of waves.While travelling , the waves collide against the internal surface and touches the sound absorbing material through holes and eventually noise is depleted.

ADVANTAGES:

- Back pressure is never a problem.
- Smooth operation
- Simple in manufacturing and design.
- Maintenance cost is less.
- Very efficient at the end.

DISADVANTAGES:

Cost is average , but is high compared to reactive muffler.

High pressure wave directly enters into the atmosphere.

HC and other effluent gases enter directly into the atmosphere.

2)*Reactive muffler:*

Reactive muffler is a special type of muffler which demotes noise and pressure both at the same time is called reactive muffler.

Construction:

The reactive muffler has two perforations (perforation is hollow cylinder tube whose one side

 @ 2013-2017 http://www.ijitr.com All rights Reserved.

is held circumferentially).These are placed in the chamber with the help of support beams or plates.The reactive muffler contains several parts like resonating chamber ,expansion chamber and tail pipe.Expansion takes place in expansion chamber and the outer space is used for fitting tail pipe.

WORKING:

In this design , there is no direct connection between inlet and outlet ports.The gas which enters the inlet port will encounter the perforators and expand.After that, the gas gets expanded in the expansion chamber and in the next step enters into outlet perforator and eventually comes out from the tail pipe.

While travelling the entire distance , pressure and noise gets significantly diminished.

ADVANTAGES:

- Design is simple
- Affordable cost
- Particles like HC,CO are easily deposited inside the chamber.
- Pressure can be reduced to atmospheric pressure.
- Not very heavy compared to absorptive muffler.
- Maintenance cost is less.

DISADVANTAGES:

- Because of high back pressure , wear and tear takes place at the exhaust valve.
- Extreme vibrations are produced.
- Engine performance gets reduced.
- Operation is rough at high speed,
- Generally, while manufacturing automobiles , the manufacturer prefers reactive muffler because of its ability to filter particles like HC,CO compounds etc.Nevertheless , because of high back pressure heavy loads act on the exhaust valve.The performance of the exhaust valve effects the efficiency of the engine .
- Storage of high pressure momentarily creates vibrations on the chamber which causes annoyance to the passengers.This is the reason why most vehicle owners prefer absorptive muffler (this muffler has nothing to do with back pressure in its operation).
- Eventually we can conclude that absorptive mufflers are more efficient and desired than reactive mufflers.

IV. FACTORS INFLUENCING THE DESIGN OF MUFFLER

While designing any product there are some factors that need to be considered.Here are some factors which are vital in designing a muffler.

- Adequate insertion loss
- Back pressure
- Size
- Durability
- Desired sound
- Cost
- Shape & style
- Tail pipe design
- Engine speed
- Number of cylinders utilised

ADEQUATE INSERTION LOSS:

- The main function of the muffler is it ‘muffle’ or attenuate sound.An effective muffler will reduce sound pressure of the noise source to the required level.In the case of automotive muffler, the noise in the exhaust system generated by the engine is to be reduced.
- A mufflers capability or its attenuating performance is generally defined in terms of transmission loss or insertion loss.Insertion loss is defined as the difference between the acoustic power radiated without and with a muffler fitted.The transmission loss is defined as the difference between the sound power incident at the entry to the muffler to that transmitted by the muffler.
- A muffler design must define the required insertion loss so that a suitable style of muffler can be designed for a specific purpose.
- As a general principle , when designing an automotive muffler , a reactive muffler with many area discontinuities.The addition of sound absorptive material will always increase the attenuation capacity of a muffler , but should be located at the appropriate place

V. DESIGNING AND CALCULATION OF MUFFLER

A muffler have been designed which is of supercritical grade type and includes all the three attenuation principles i.e., reactive, followed by absorptive type muffler, and a side branch resonator. The interesting events of the design are continuous volume reduction of chambers in the reactive part, the flow pipe cross-sectional area is maintained constant throughout, a layer of insulation outside the reactive part, the placing of side branch resonator compactly, option for tuning the resonator using a screw and cylinder.

 @ 2013-2017 http://www.ijitr.com All rights Reserved.

A. DESIGN DATA

For the experiment, an existing petrol engine has been used. Calculations are done on the basis of data collected from the engine; however, some data are applicable to all engines. For designing, the following data are required.

1) *SOUND CHARACTERISTICS (WITHOUT SILENCER)*

Rpm of the engine= 2026

2) *SOUND ANALYSIS WITH FREQUENCY ANALYZER (TO OBTAIN THE DOMINATING FREQUENCY)*

Two dominating frequencies, the low level and the high level have been obtained. These are:

Frequency Level	Frequency (Hz)
Low	270
High	40000

3) *DIAMETER OF EXHAUST PIPE OF ENGINE/INLET PIPE OF MUFFLER*

The Exhaust Pipe diameter: 1.5 inch

4) *4.THE THEORETICAL EXHAUST NOISE FREQUENCY RANGE*

From various experiments is has been found that the theoretical exhaust noise frequency is 200-500Hz.

B. REFLECTIVE PART DESIGN

Exhaust pipe diameter = 1.5 inch

The dimensions to determine are that of the chamber length L and the body diameter.

To determine L, three methods have been used. They are as follows:

(1) First method used to determine L

Maximum attenuation occurs when

$L = n\lambda/4$…….(1.1)

where, λ = wavelength of sound (m or ft)

n = 1, 3, 5, …….(odd integers)

Since λ is related to frequency by the speed of sound, one can say that the peak attenuation occurs at frequencies which correspond to a chamber length.

The range of frequency is obtained from the design data in section. The following table of L has been constructed with this data.

C. CALCULATED WAVELENGTH FROM FREQUENCIES

From Table, we can find that L has a range between 6.72

Frequency	λ = C/f (m)	Λ (inch)	n = odd integer	L (inch) L = $n\lambda/4$
N(min) 200 Hz	1.65 (λmax)	67.2 (λmax)	1 3	16.4 50.4
N(max) 500 Hz	0.66 (λmin)	26.9 (λmin)	1 3	6.72 20.16

Table. 2: Calculated Wavelength

	SOUND LEVEL
Without any load	104.5 dbA
50% load	106.5dbA
100% load	107dbA

Table. 3: Sound Level

From Table, we can find that L has a range between 6.72 and 50.4 inch. Due to space limitation, the length of the small chamber has been chosen to be 6.72 inch and 20.16 or 20 inch for the whole of the chambers.

(2) Range of chamber length considering the temperature of exhaust gas

Another factor which must be considered in expansion chamber design is the effect of high temperature of exhaust gases. This factor can easily be included in the design by using the following equation:

$0.5\ (49.03\sqrt{°R})\ /\ 2\pi f \le L \le 2.6\ (49.03\sqrt{°R})\ /\ 2\pi f$……. (1.2)

where, $\sqrt{°R}$=absolute temperature of the exhaust gas

f = frequency of sound (Hz)

Let the temperature of exhaust is assumed to be 759.7º R

Putting this value in equation (1.2),

We obtains,

$0.5\ (49.03\sqrt{759.7})\ /\ 2\pi 270 \le L \le 2.6\ (49.03\sqrt{759.7})\ /\ 2\pi 270$

(here, f =270Hz for low frequency reactive muffler)

0.4 ft ≤ L ≤ 2.04 ft

From the 1st method, L = 20 inch = 1.67 ft.

So the condition of 0.4 ft ≤ 1.67 ≤ 2.04 ft is satisfied.

(3) Range of chamber length according to ASHRAE Technical Committee 2.6

According to ASHRAE Technical Committee 2.6, muffler grades and their dimensions, the requirement matches with the super critical grade.

IL = 35 to 45 dBA

Body/Pipe = 3

Length/Pipe = 10 to 16

That is, 10 × pipe dia ≤ L ≤ 16 × pipe dia

10 × 1.5” ≤ L ≤ 16 × 1.5”

15” ≤ L ≤ 24”

 @ 2013-2017 http://www.ijitr.com All rights Reserved.

Again the chosen length L = 20 inch, satisfies the above condition

D. TAILPIPE DESIGN

According to equation (1), resonance occurs when L= nλ/2. So, for an economical construction, the value of **n** may be taken as 1. Then the tailpipe must be less than λ/2.

So from the table we can find the tail pipe length 3.36 inch or less than it.

VI. OPERATIONAL AND PHYSICAL PARAMETER

A. PERFORATED TUBE

Perforated tube diameter is 1.5 inch because engine exhaust manifold dia. is same and 12 inch long as per design data and made from the stainless steel because it has a high melting point 1510o C

Fig. 2: Perforated tube

B. EFFECT OF CHANGE IN POROSITY AND CHANGE IN DIAMETER OF PERFORATION HOLE ON BACKPRESSURE

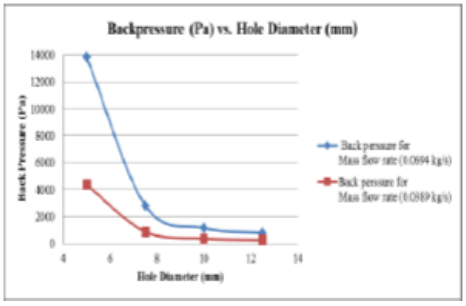


Fig. 3: Effect of Change In Porosity

From fig- it is observed that for the smallest hole diameter of 5 mm the back Pressure is as high as 13,837 Pa. If we increase the diameter of the hole Back Pressure rapidly falls down and it is lowest i.e. 788 Pa for the hole diameter 12.5 mm. The pressur e drop is very large which is 75% of highest backpressure for first two hole diameters viz. 5 mm and 7.5 mm. For other hole diameters the pressure drop is small but significant.

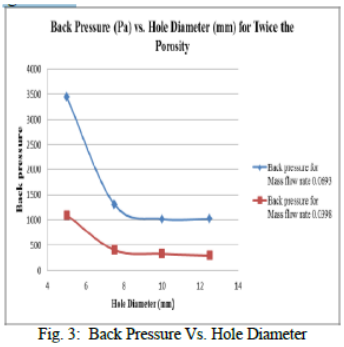
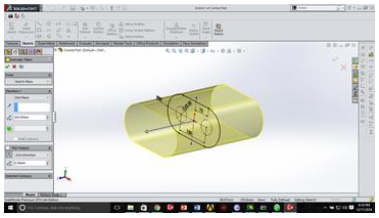
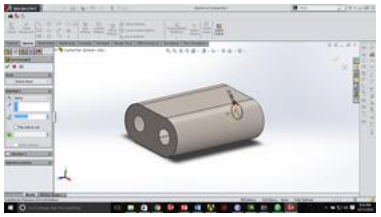


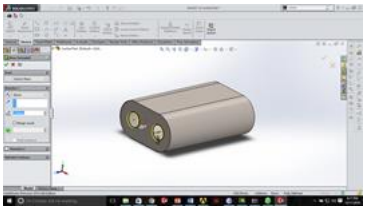
Fig. 3: Back Pressure Vs. Hole Diameter

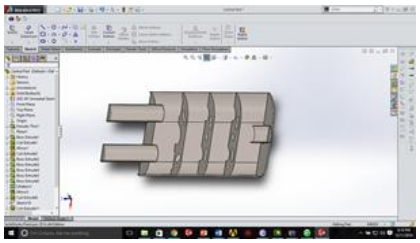
When the porosity is doubled than the conventional, backpressure drops by 75% for first two hole diameters. While for other hole diameters it is fairly the same value with a difference of 20 Pa to 75 Pa. Thus it can be seen that the backpressure value is high for small diameters as compare to bigger diameter holes even if the porosity is doubled. But for higher diameters the Backpressure value remains the same even when the porosity is doubled.

Design Procedure

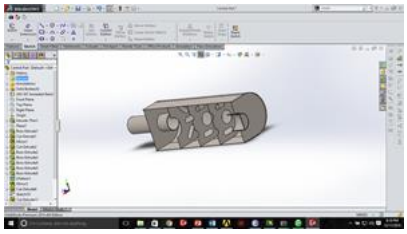




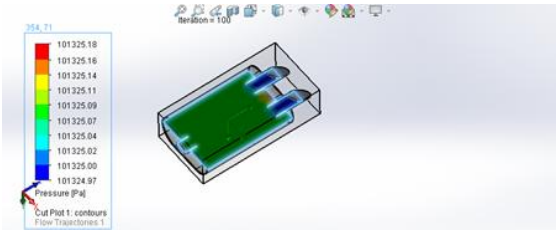




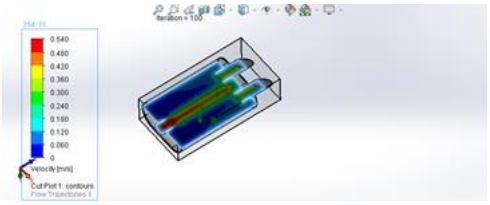
 @ 2013-2017 http://www.ijitr.com All rights Reserved.



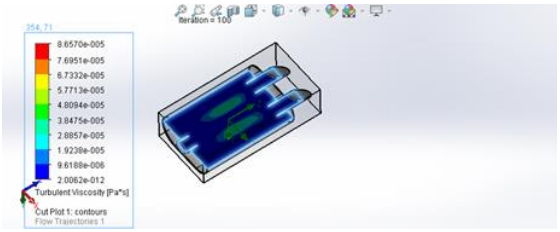
RESULTS

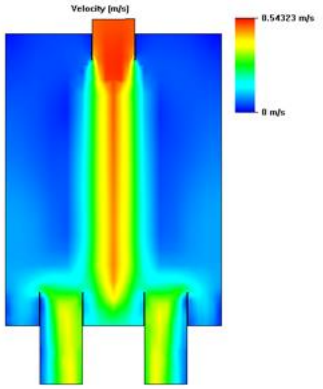


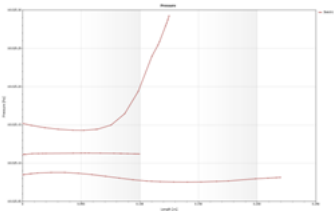
Pressure Distribution



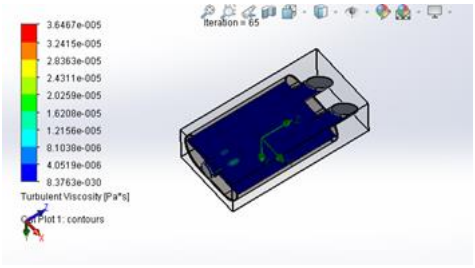
Velocity Distribution

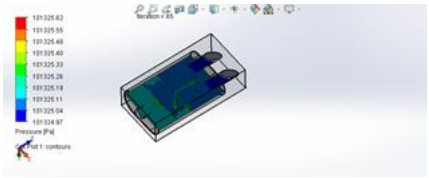




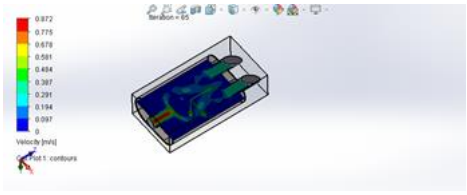


CFD analysis with Baffels

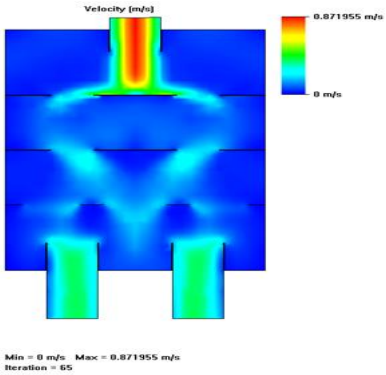




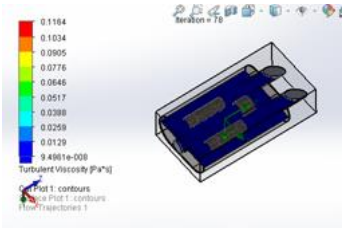
Pressure Distribution



Velocity Distribution

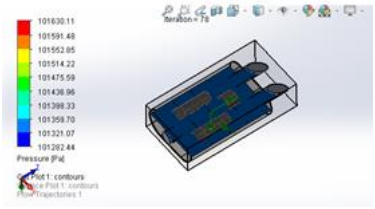


CFD analysis with Baffels and Pipes

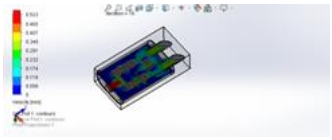


 @ 2013-2017 http://www.ijitr.com All rights Reserved.

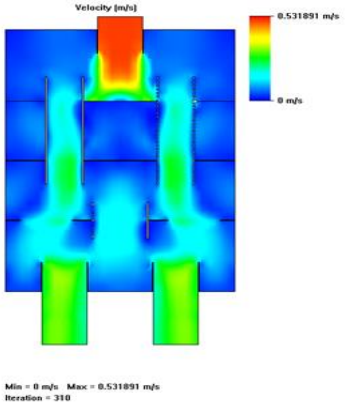
Turbulence



Pressure Distribution



Velocity Distribution



VII. CONCLUSION

The various dimensions of the muffler are varied keeping some dimensions constant and then the effect on velocity is observed. It can be seen that the velocity varies nonlinearly and it cannot be predicted by any equation. Varying the Design the muffler has pronounced effect on the backpressure. The Velocity is reduced greatly if the area consumed is doubled. Also if the diameter of the hole is increased the backpressure decreases sharply. The change in diameter of holes has remarkable effect. There is sharp change in Velocity values even if hole diameter is slightly changed. Three mufflers were tested in CFD with varying Design. There was a sudden decrease in backpressure values as Pipe was introduced. The CFD values and Experimental values are in good agreement with each other

VIII. REFERENCES

[1] Key Fonseca De Lima, Arcanjo Lenzi, Renato Barbieri; "The Study of Reactive Silencers by Shape and Parametric Optimization Techniques", Applied Acoustics 72 (2011) pp.142–150.

[2] Jesus Blanco, Andrew Earnshaw; "Study Of the Noise Characteristics of Motorcycle Silencers", SAE 2001 World Congress Detroit, Michigan March 5-8, 2001.

[3] John Perkins, Jay Robichaud, Brian Ellis, "Advanced Two-Stroke Tuned Exhaust System" Mee 487 & 488 Design Iii &Iv".

[4] Peter Hield; "The Effect of Backpressure on the operation of Diesel Engines", Maritime Platform Division, Defense Science and Technology organization, DSTO-TR-2531, Australian Government (Unclassified).

[5] Ying-Li Shao; "A Study on Exhaust Muffler Using a Mixture of Counter phase-Counteract And Split-Gas Rushing", Advanced In Control Engineering And Information Science, Engineering 00 (2011) pp.4409-4413.

AUTHOR BIO-GRAPHY

BHAGATH SHAILENDER was born in thurkala maddikunta (Vill), peddapalli (M), karimnagar (Dist.),Telangana, India, in 1993. He received the B.Tech. degree in Mechanical engineering from the **NALLA MALLA REDDY ENGINEERING COLLEGE ghatkesar,** Under JNTUH Affiliation, India, in 2014, and Pursuing M.Tech Thermal Engineering From **DVR College of Engineering And Technology** under JNTUH, in kashipur, Sangareddy, India.

A.Rajnikanth was born in Udumnalli (Vill), Humnabad(Taluka) Bidar (Dist) Karnataka, India, in 1986. He received the B.E. degree in Mechanical Engineering from the Visvesvaraya Technological University Belgaum, Karnataka India, in 2008, the M.Tech, in Thermal Power Engineering from Visvesvaraya Technological University Belgaum, Karnataka India, in 2013.

In 2009, He joined as Quality Assurance Engineer in M/S Mungi Engineers Pvt.Ltd Zaheerabad and promoted to Asst. management representative(MR).In 2014,he joined as Asst. Professor in the department of Mechanical Engineering in DVR College of Engineering & Technology, Kashipur, Sangareddy dt. Telangana.

 @ 2013-2017 http://www.ijitr.com All rights Reserved.